



ChaRT

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and the ChaRT Team



I. ChaRT Overview

ChaRT (Chandra Ray Tracer) is a user friendly web interface that allows the user to simulate High Resolution Mirror Assembly (HRMA) Point Spread Functions (PSFs) at any off-axis angle and for any energy or spectrum.

<http://cxc.harvard.edu/chart/>

- ChaRT provides the user with access to the best available mirror model, including many of the details of the HRMA's physical construction and a detailed model of the re properties of the mirror surface.
- ChaRT runs remotely the *SAOsac* set of routines (used internally at the CXC for studies and calibration of the HRMA optics).
- The s/w verifies and submits user's simulation parameters and notifies the user when their files are available for download via FTP.

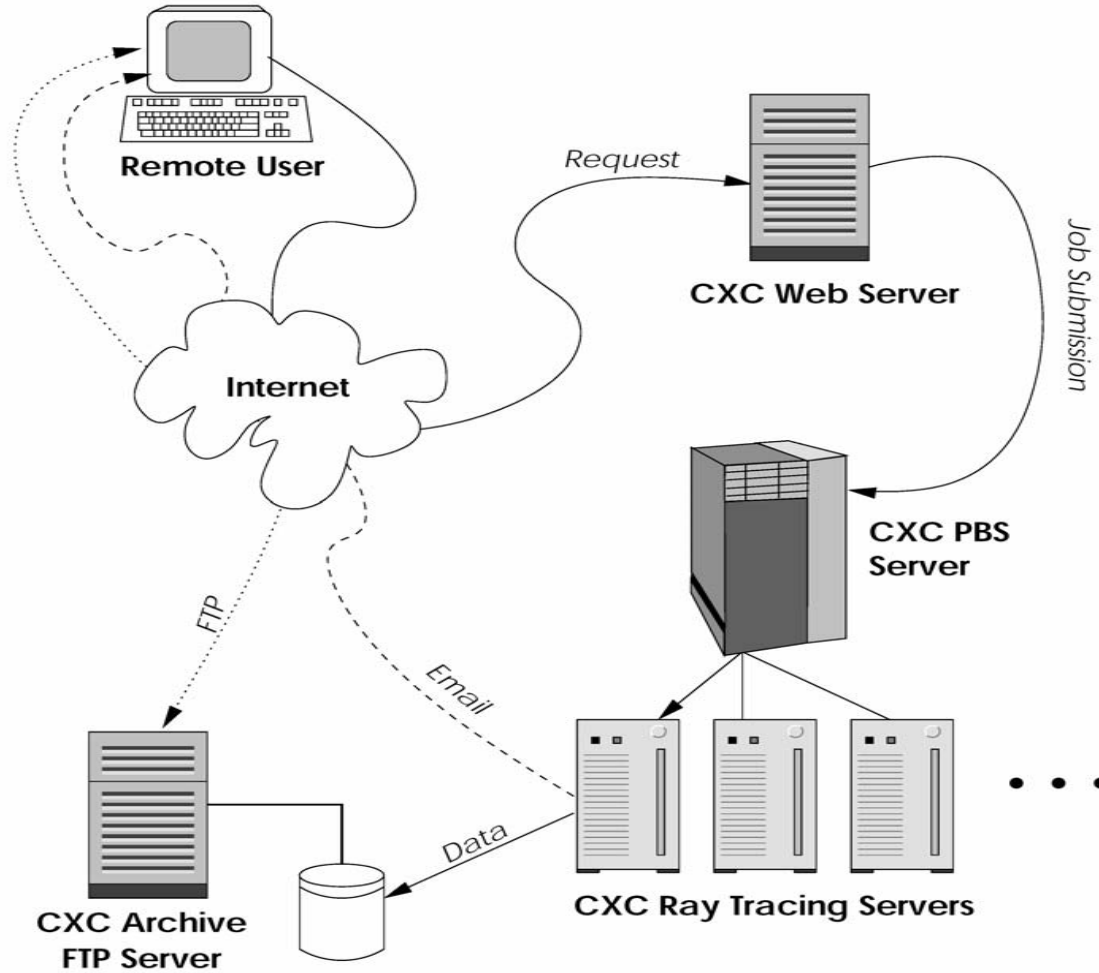


Fig. 1 – ChaRT software and hardware architecture



The output of ChaRT is a FITS table containing a collection of rays. In order to create a model PSF image it is necessary to project the rays onto the detector and take account of detector effects. This is achieved using The ChaRT rays as an input to MARX.

A set of ChaRT threads accessible from the ChaRT web page were designed to guide the user

<http://cxc.harvard.edu/chart/threads>



II. ChaRT Web Pages

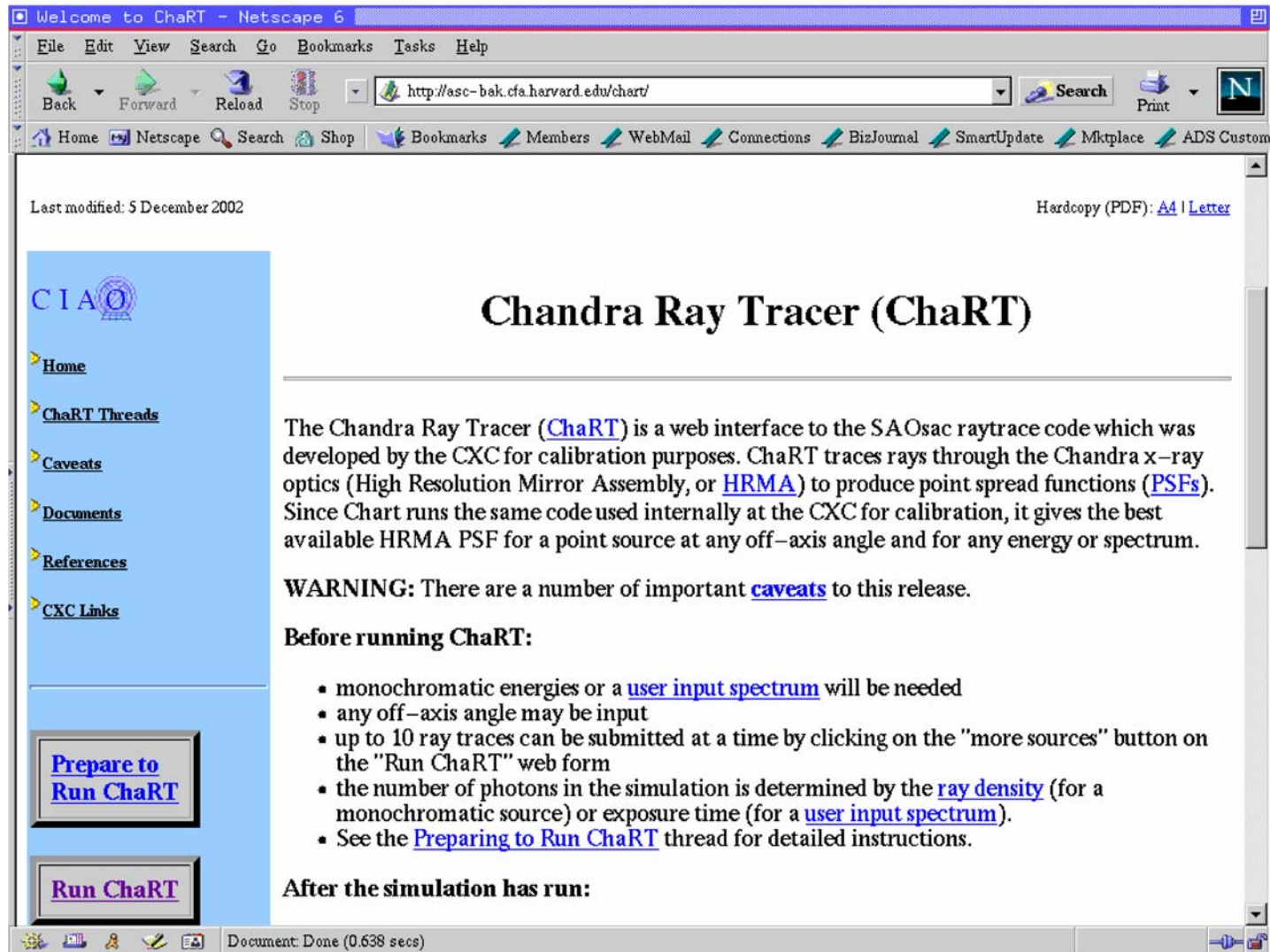


Fig. 2 – ChaRT web page - 1



Welcome to ChaRT - Netscape 6

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Run ChaRT

After the simulation has run:

- the user will receive an e-mail including:
 - a summary of the parameters used in the raytrace(s)
 - a pointer to the FTP directory where the results of the ray trace(s) are stored as *tar files*.
- To unpack the tar file type "tar -xvf filename.tar" at the unix prompt.
- After unpacking the tar file the ray trace simulation for each source will be located in a subdirectory with names such as *source1*, *source 2*, etc. The [ChaRT Output ray files](#) are FITS tables and can be very large (100 – 1000 Mb, approximately 4 – 40 million photons).
- Follow the [MARX thread](#) to learn how to project rays onto the detector.

The output of ChaRT is not an image but a collection of rays. In order to create an image of the PSF it is necessary to project the rays onto the detector. Using MARX it is possible to perform this projection and also take into account detector effects.

The [MARX thread](#) provides step by step instructions for creating a PSF image. The resulting PSF may be compared to real data, or used for planning of Chandra Observations (see the [caveats](#)).

Please note that blur due to satellite dithering is not included in ChaRT. Please see the [ChaRT caveats page](#) for details.

Frequently Asked Questions

- Why ChaRT rather than the [standard PSFs libraries](#)?

Last modified: 5 December 2002

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Fig. 3. – ChaRT web page - 2

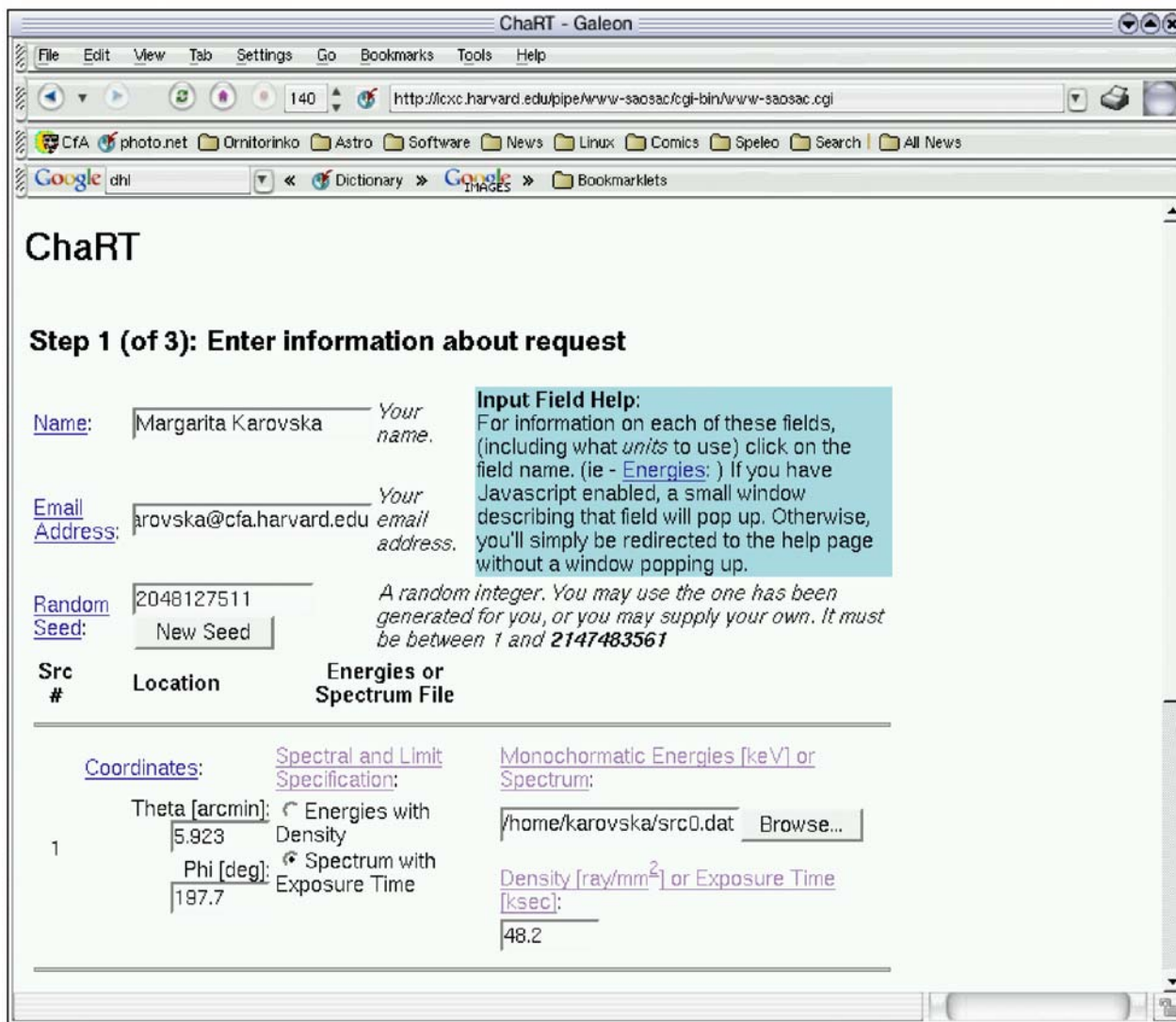


Fig. 3. – ChaRT parameter interface



From: ChaRT <cxc_rays@head-cfa.harvard.edu>

Message-Id: <200212122036.PAA13443@young.cfa.harvard.edu>

Content-Type: text

Your job has completed. You may retrieve your files from our anonymous ftp data server, where they will be stored for no more than 2 days. Pertinent information is listed below. Thank you.

====[This is an automated email. Do not respond to this address.]====

====[If you need help, please contact cxchelp@head-cfa.harvard.edu]====

Host: cda.cfa.harvard.edu

Username: anonymous

Password: karovska@cfa.harvard.edu

Directory: /pub/traceftp

Filename: karovska-20021212-153643.tar.gz

File size (approx, untarred, [MiB]): 0

URL: ftp://cda.cfa.harvard.edu/pub/traceftp/karovska-20021212-153643.tar.gz

Job Parameters:

Name = Margarita Karovska

Email = karovska@cfa.harvard.edu

Random Seed = 1337910590

Source 1

Coord Sys = Theta/Phi

Theta [arcmin] = 5.923

Phi [degree] = 197.7

Spectrum = src0.dat

Exp. Time [ksec] = 48.2

Fig. 5. -- E-mail to the user

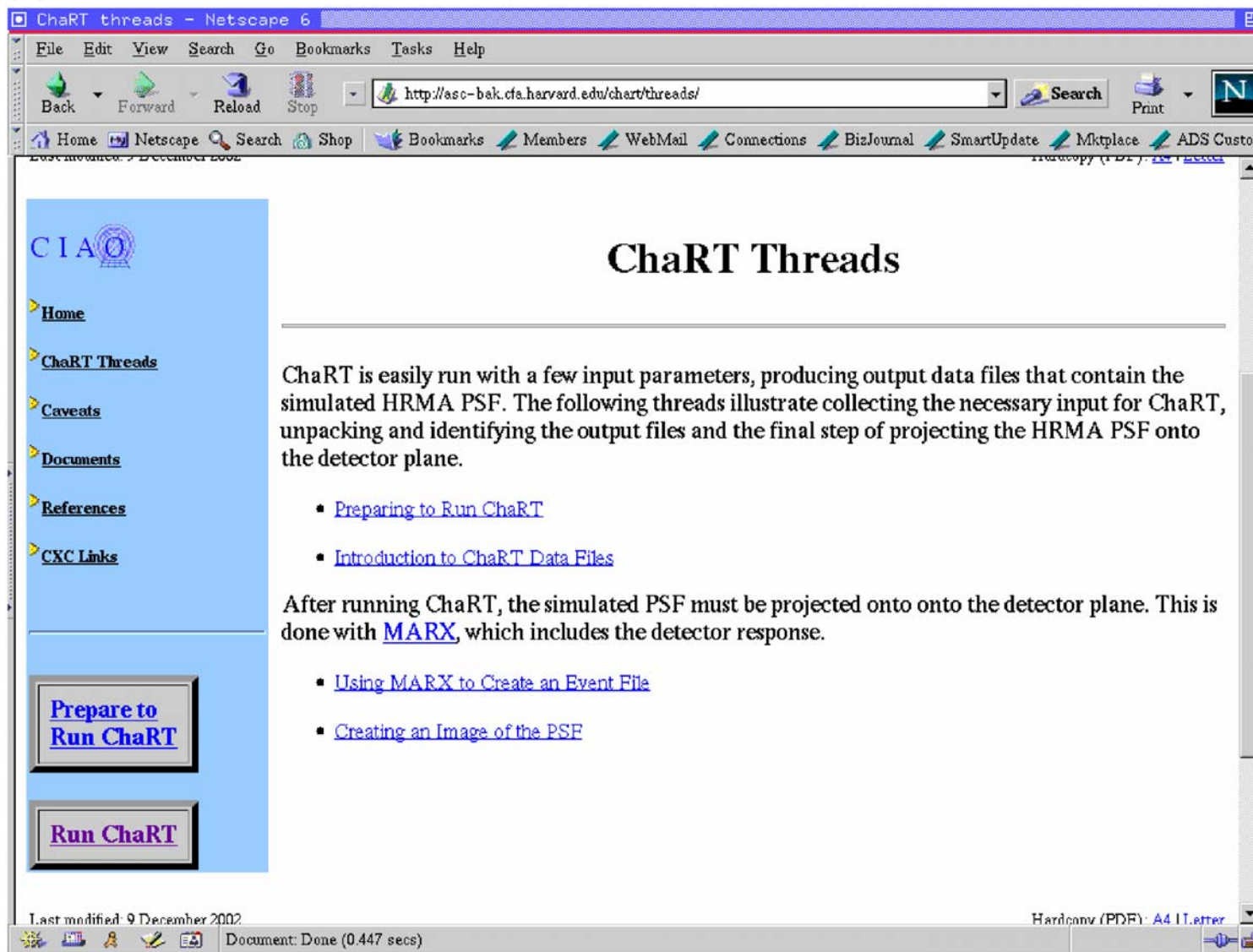


Fig. 6. – ChaRT threads



Using MARX to Create an Event File - ChaRT - Netscape 6

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Using MARX to Create an Event File

ChaRT Threads
(13 December 2002)

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The [output of ChaRT](#) is a set of rays (a PSFRAYS table) which cannot be used directly in your analysis; it must be converted into a suitable format, i.e. a pseudo event file. This thread shows how to use [MARX](#) to project the rays onto the detector plane.

Using MARX allows us to take into account all changes to the photon distribution emerging from the HRMA due to the detector response. In particular, the detector [QE](#) & [QEU](#) and the roll are accounted for. In addition to simulating the detector response, MARX uses the ray weights to account for the mirror effects, i.e. different efficiency of different shells at different angles/energies. Please read the [Caveats page](#) before beginning, in order to be aware of what is **not** included.

This example uses `HRMA_theta5.949_phi197.7_en1.7_d2.fits`, which was created in the [Introduction to ChaRT Data Files](#) thread. The level=2 event file for ObsID 942 (ACIS-S, NGC 4244), which can be downloaded from the [Chandra Archive](#), is also needed.

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Fig. 7. – ChaRT-MARX thread



III. Examples

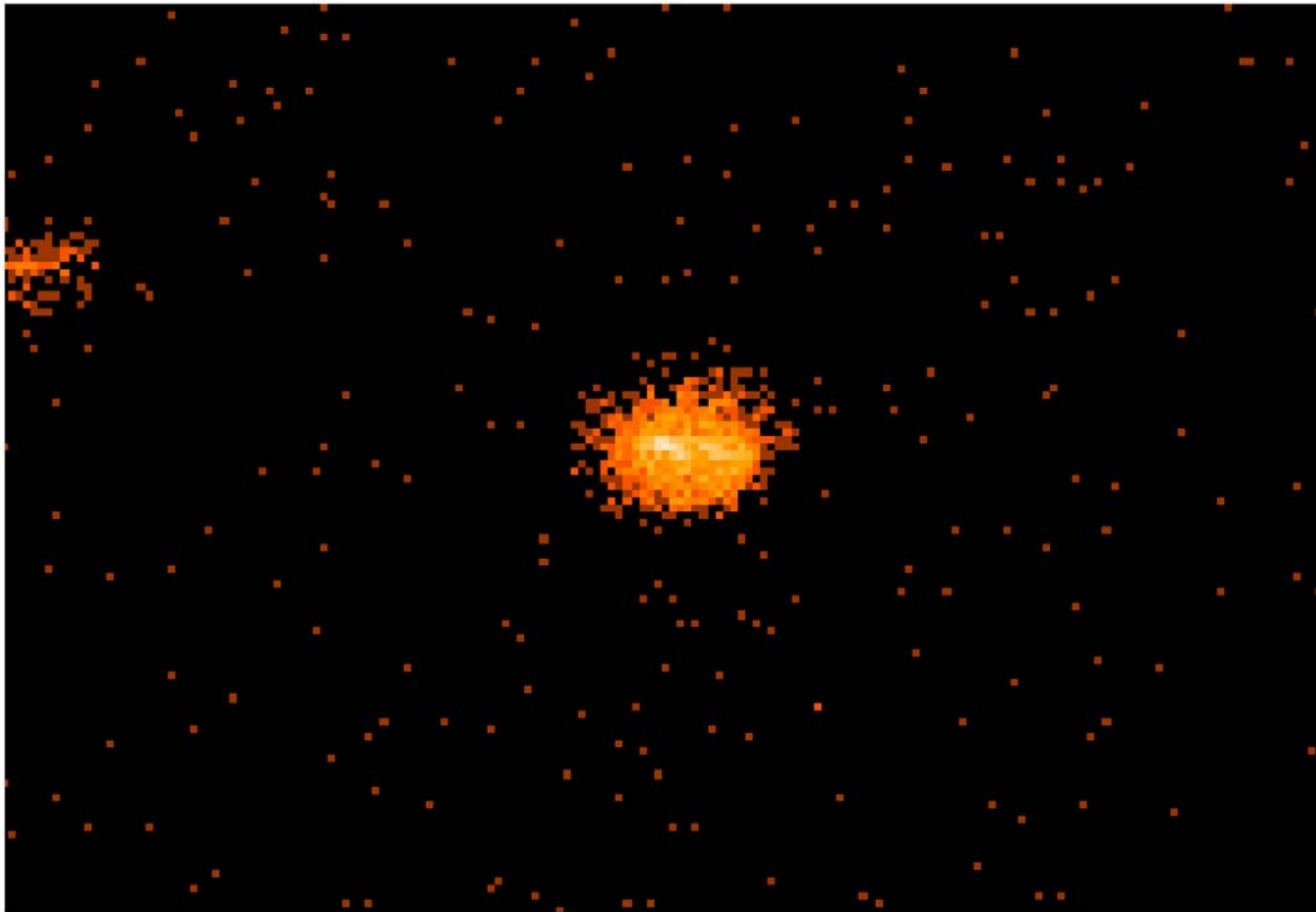


Fig. 8. – ACIS-S observation of a source at 6' off-axis angle (source 1)

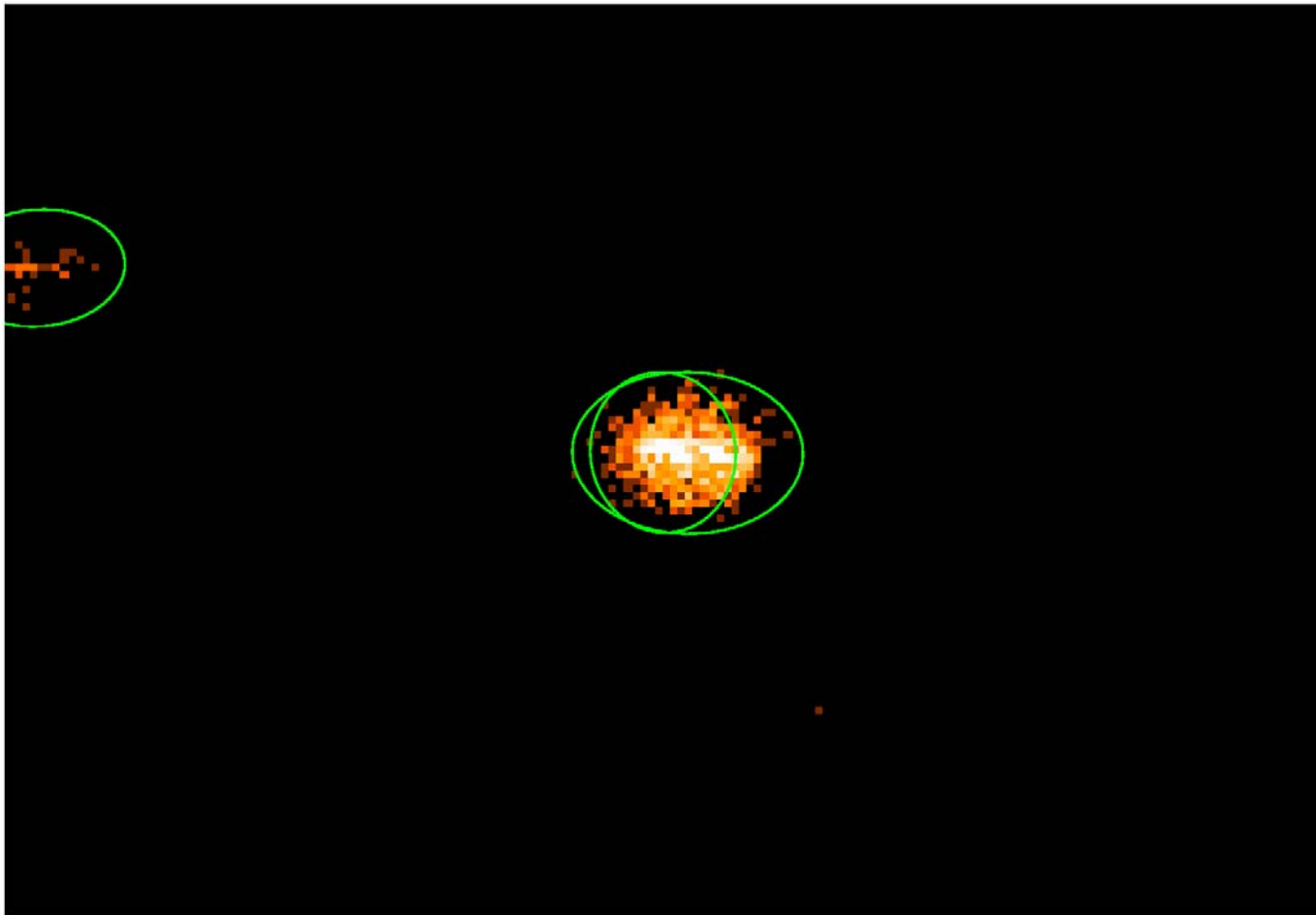


Fig. 9. – Wavedetect result for source 1

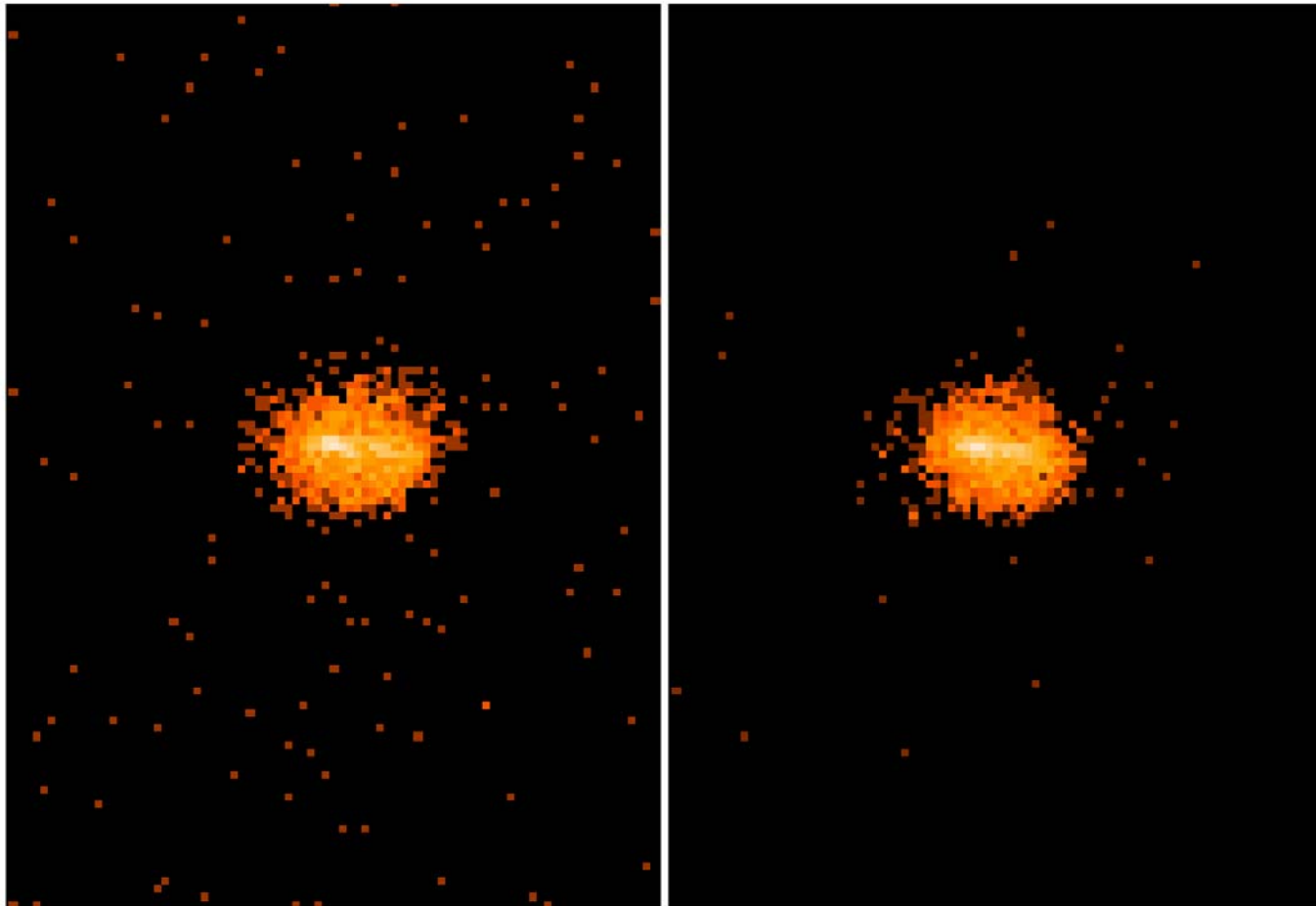


Fig. 10. – Source 1: observation vs. PSF

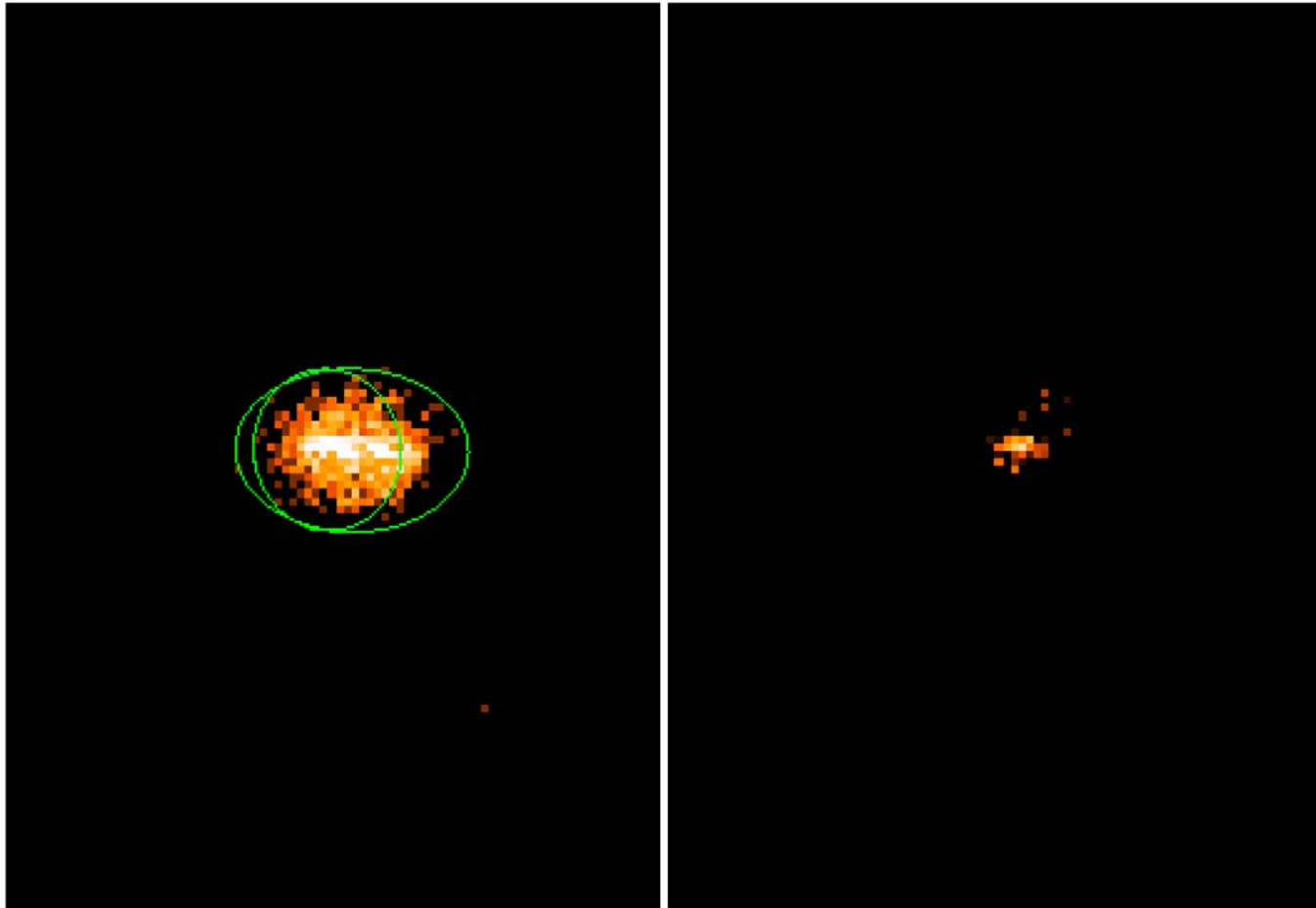


Fig. 11. – R-L deconvolution of source 1 with ChaRT PSF

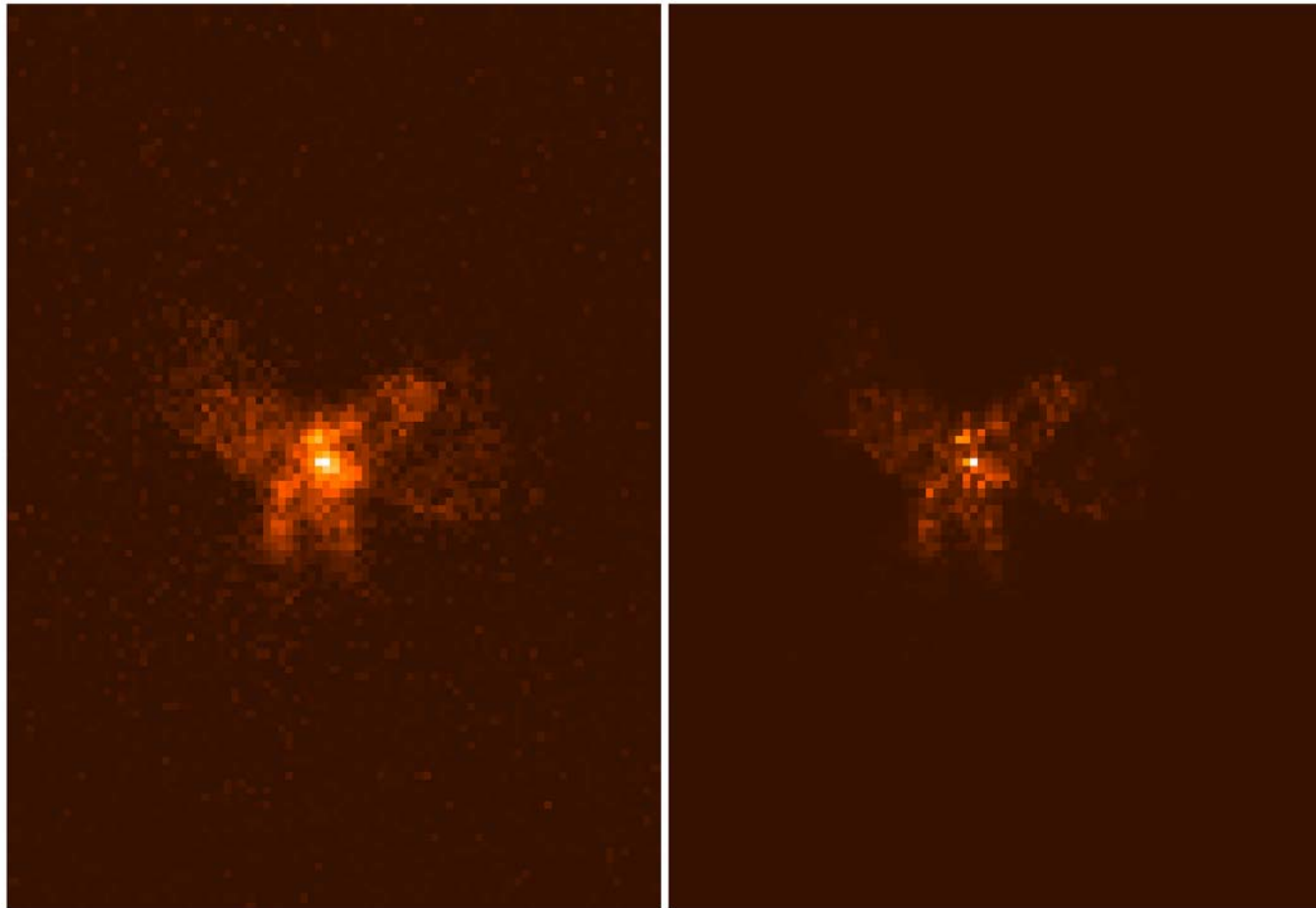


Fig. 12. – NGC6240 – galaxy with two giant black holes 2'' apart: (left) original ACIS-S observation, (right)- a deconvolution using ChaRT/MARX PSF



IV. Why ChaRT rather than the standard PSFs libraries?

PSF libraries/mkpsf:

The standard PSF library files consist of 2-D simulated monochromatic PSF images “postage stamps” (only for 5 monochromatic energies ranging from 0.277 keV to 8.6 keV), made using SAOsac and projected onto ideal detector planes. They are stored in multi-dimensional FITS hypercubes with az and el steps (in telescope fixed system) of either 1 arcminute or 5 arcminutes. The user can extract a PSF model image from a library file by interpolating within the energy and off-axis angle grids, using *mkpsf*. The usage of the standard PSFs libraries (with *mkpsf*) for a detailed spatial/spectral analysis has limitations including:

- interpolation over the coarse energy and spatial grids, especially for large off-axis angles.
- monochromatic energies only
- number of photons (rays) fixed
- no instrument effects included



ChaRT

The main advantages of ChaRT include:

- ChaRT simulates a PSF for ANY POINT on the detector and any energy (OR SPECTRUM) with no interpolation
- the user selects the number of photons (rays)
- ChaRT-MARX thread allows the user to make the best currently available model PSF for their analysis, including instrumental effects



V. Future Developments

- adjust the limits based on users requirements (eg. No. of sources, exposure, density)
- include aspect simulation in SAOsac
- provide a set of precomputed spectral models
- FITS image file input as the image model
- canned PSFs (cached ChaRT simulations)?
- usage of scripts, future of hypercubes, mkpsf (and other users suggestions)